Financial protocol for South Africa's climate change mitigation assessment

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SUMMARY OF GUIDELINES

Scope of assessment

- Analysts should not limit sectoral assessment to only abatement options, but should consider the broader set of mitigation options
- Sectoral analysts should consider both short and long term reduction options in the overall assessment.

Reporting units

- GHG emissions should be reported in mass units of CO_2 (not carbon), CH_4 and NO_2.
- GHG emissions should be converted into CO_2 equivalents using Global Warming Potentials provided.

Analytical tools and parameters

- Economic analysis (as opposed to financial analysis) should be undertaken for each project and sector
- Cost-effectiveness analyses (where the costs of meeting alternative emission reduction targets are assessed) should be undertaken for each project and sector.
- Future costs and benefits should be discounted to the present using discount rate stipulated.
- Costs and benefits that can be quantified in the cost-effectiveness analysis should be included. Other costs and benefits should be reported as per instructions in the documents "Criteria for evaluating mitigation options" and "Instructions to project leaders"
- The life cycle costs of the mitigation options and baseline should be calculated by discounting all of the costs of these options to a present value.
- These life cycle costs should then be levelised, so they are expressed in Rands per year.
- The cost effectiveness analysis should be based on the difference in the levelised life cycle costs of the mitigation option and the baseline option (all described in detail in this report), divided by the reduction in emissions.
- The cost-effectiveness analysis should exclude taxes and subsidies, external costs, depreciation and interest payments but include private costs or costs which can easily be quantified. Implementation costs should be included.
- Analysts should also calculate the change in unit cost of production due to a mitigation project, where applicable

Assumptions/parameters

- Analysts should utilise the set of scenario, environmental and economic parameters recommended in this report.

Methodology

- A baseline scenario (defined in terms of short and long term considerations) for the sector should first be constructed. Factors to include in this baseline scenario are listed in this document. It is recommended that a bottoms-up, simulation model be utilised.
- Mitigation options for the sector should be identified. A screening process should be carried out to select options.
- The mitigation potential and cost of options should then be assessed. Analysts should undertake no primary research.
- GHG emission reduction marginal cost curves should be constructed for each sector. Directions on how to do this are provided in the text.

- Analysts should conduct sensitivity analyses of the assessments undertaken.

Way forward

- Each sectoral assessment should be presented together with a brief commentary on the limitations and strengths of the research and analysis undertaken. Recommendations for improving the studies and for future research similar to this should also be presented.

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1. Background

1.1 Introduction to the study

The South African Department of Environmental Affairs and Tourism is embarking on a Climate Change Country Study, as part of its obligations under the United Nations Framework Convention on Climate Change (UNFCCC). The study has four elements: (i) greenhouse gas emissions inventory; (ii) vulnerability and adaptation assessment; (iii) mitigation options; and (iv) policy development. This report details a recommended economic costing protocol for sectoral mitigation assessments.

1.2 Rationale for this report

Unlike some other countries in southern Africa, a range of analysts and individuals will be responsible for the South African mitigation assessment. This report serves to deliver a protocol detailing common cost concepts, parameters and a common analytical and methodological structure for the analysts. For a number of reasons, it is critical that a common approach is used for each assessment. Firstly, every sectoral assessment (i.e. for energy, industry, households and commerce, transport, land-use and agriculture) should comprise an aggregation of project-level mitigation options. These project-level options must be integrated and then assessed on a sectoral level. This can only be satisfactorily done if the approaches underlying each sector's project-level assessments are comparable. Secondly, the mitigation options outlined in each of the sectoral studies will be integrated into a macroeconomic assessment. Again, if this is to be done successfully, similar sector-level approaches must be adopted. Thirdly, because climate change is a global environmental issue, it is likely that South Africa's mitigation assessment (along with the mitigation components of other country study initiatives) will ultimately contribute to a global mitigation assessment, and for investment purposes in particular should thus conform to an internationally accepted approach adopted by other countries.

The broad guidelines presented in this report should not be seen as limiting the research and analysis undertaken by each of the project teams. On a sectoral level, for instance, the aim is not to define specific parameters for each study but rather to describe a broad framework according to which the studies should be undertaken. It is assumed that the various project teams will have a better understanding of specific variables and parameters associated with the sector they are researching and should thus be free to adopt the best possible detailed approach for the sector. With regard to the global relevance of South Africa's mitigation study, the importance of the guidelines is not so much in the economic and non-economic parameters presented, but in the broad analytical approach adopted. Clearly, national climate change mitigation studies will vary in coverage, details and sophistication of effort.

1.3 Scope

The defining concepts, parameters, and approaches presented in this report should be utilised by all project analysts undertaking both project- and sector-level assessments. This protocol should be read in conjunction with the "Instructions to Sectoral Project Leaders", as well as "Criteria for evaluating mitigation options".

1.4 Sources[1]

This report draws substantially from a 1998 report written by the United Nations Environment Programme's Collaborating Centre on Energy and the Environment entitled *Economics of Greenhouse Gas Limitation: Technical Guidelines.* This report is one of the main outputs of a Global Environmental Facility (GEF) project, aiming to establish a methodological framework for climate change mitigation assessment, with particular emphasis on the needs of developing

1 Dr Clive van Horen's invaluable help with this project is also gratefully acknowledged.

countries.[2] Other climate-change related sources include the guidelines developed by the Intergovernmental Panel on Climate Change (1995; 1996), United States Country Studies Programme (USCSP) case studies, and GTZ's 1992 to 1998 climate change country study experiences. In addition to this, Swisher, Jannuzzi and Redlinger's (1998) *Tools and Methods for Integrated Resource Planning* proved useful.

1.5 Outline

Following this introduction, we introduce the basic economic and environmental concepts and tools for mitigation costing in Section 2. Section 3 presents the overall methodology for the project and sectoral assessments, while Section 4 provides the recommended parameters for the sectoral analysts to use in their calculations. Section 5 then outlines the specific steps for project-level costing, followed by an example of how to analyse a mitigation project in Section 6. Finally, Section 7 points to some useful sources of information on greenhouse gas mitigation technologies.

2. Concepts and analytical tools

In this section, various important concepts and tools are introduced. These are broken down into the following categories: (i) climate change concepts; and (ii)economic cost concepts. The purpose of this section is twofold. Firstly, it equips project teams unfamiliar with these concepts with an overview of them. Secondly, it seeks to ensure that the concepts used by the project teams are standardised.

2.1 Climate-change concepts

2.1.1 Mitigation and abatement

Activities that aim at a reduction of the net amount of GHGs released into the atmosphere, and thus help to slow down the process of anthropogenic climate change, are called **mitigation** measures. In other words, mitigation is 'to make less severe'. Mitigation measures include both emission abatement and sink enhancement, and cover all greenhouse gases, as well as all economic sectors and activities where emissions occur. Mitigation activities undertaken in developing countries are eligible for incremental cost funding under the UNFCCC.

Abatement refers to activities undertaken to reduce the emission of GHGs into the atmosphere. In other words, abatement is 'to make or become less'. Abatement measures are a subset of mitigation activities; other main mitigation measure include the enhancement of sinks (UNEP 1993b).

Sectoral analysts should not limit assessments to abatement measures but should consider the broader set of mitigation options.

2.1.2 Reduction options

Reduction options refer to technical measures in various sectors which have the potential to reduce GHG emissions. Reduction options can be classified as short- or long-term options. Reduction options may not necessarily be implemented now, but could be recommended for implementation in the future (i.e. reduction options have different dates of implementation). This could be because costs are expected to decline in the future, for example. Where this is the case, sectoral analysts should ensure that their calculations reasonably estimate the future cost of the option.

Sectoral analysts should consider both short and long term reduction options in the overall assessment.

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2 Analysts are encouraged to read the UNEP (1998) report for additional guidelines on specific sectoral assessments.

2.1.3 Carbon dioxide, methane and nitrous oxide emissions

A standard for emission inventories has been defined by the IPCC (1995a; 1995b). Relevant GHG sources are listed in Table 1 below.

Emission	Main/principal Emission sources
CO_2	Fossil fuel combustion Decrease in biomass stock Cement and lime production
CH_4	Combustion Oil and gas Coal mining Enteric fermentation Animal waste Landfill/sewerage treatment Rice production Forest and savannah burning
N_20	Combustion Agricultural soils

Table 1: Emission inventory for CO_2, CH_4, N_20
Source: UNEP Collaborating Centre on Energy and Environment (1998)

GHG emissions should primarily be reported in mass units of CO_2 (not carbon (C)), CH_4 and N_2O.

This allows subsequent conversion into other units. GHG emissions can also be converted into CO_2 equivalents. *Analysts can undertake this conversion using global warming potentials, described in sections 2.1.4 and 4.3.2.*

2.1.4 Global warming potentials

The weight and effect of different GHGs varies enormously. In 1990, for example, it was estimated that CO_2 accounted for more than 98 per cent by weight of the total emissions of the five main GHGs. The contribution of CO_2 to the total GHG effects for 1990 was, however, much less than 98 per cent because, ton-for-ton, its impact on global warming is lower than for other gases.

Global Warming Potentials (GWPs) take the different strengths into account thereby enabling the analyst to show the relative importance of different GHG emissions. The direct GWP of methane, for example, is defined as the *cumulative direct effect* on the atmosphere's energy budget resulting from a one-kilogramme release of methane, relative to the direct effect of a one-kilogramme release of CO_2.

2.1.5 Kyoto Protocol

The Conference of the Parties (COP) was established under the UNFCCC to review the implementation of the Convention, as well as to adopt amendments, protocols and decisions to promote the effective implementation of the Convention. During the course of COP1, the Parties agreed to establish a process for strengthening the Annex 1[3] countries' commitments contained in the Convention. This was achieved in the form of the Kyoto Protocol (1997), which is an instrument separate from but related to the Convention: it reaffirms the

[3] The countries listed in Annex 1 of the UNFCCC are developed countries, or countries whose economies are in a state of transition. Parties that are not listed in Annex 1 are developing countries. The Convention places more obligations on Annex 1 than non-Annex 1 countries. South Africa recently ratified the Convention as a non-Annex 1 country (NCCC 1998).

commitments set out in the Convention. Under this Protocol, Annex 1 parties are obliged to undertake certain activities such as:

- implement policies on climate change, or further elaborate their policies;
- enhance energy efficiency;
- limit and/or reduce emissions in the waste, energy and transport sectors;
- protect sinks for GHGs[4];
- phase out market instruments that are counter productive to the aims of the Protocol (such as some subsidies); and
- promote sustainable forms of agriculture and associated research.

Finally, the Kyoto Protocol provides for the establishment of the Clean Development Mechanism (Article 12) as described in section 2.1.6 below (NCCC 1998).

2.1.6 Joint implementation, activities implemented jointly, and the clean development mechanism

Joint implementation (JI) is a concept that, if implemented through the UNFCCC, would allow nations to meet their obligations to reduce net GHG emissions by investing in mitigation projects in other countries and claiming a share of the resulting emissions reduction credits. This concept has its roots in Article 4.2 of the UNFCCC which states that:

> The developed country Parties and other Parties included in Annex 1 commit themselves specifically as provided for in the following:
>
> (a) Each of these parties shall adopt national polices and take corresponding measures on the mitigation of climate change....
>
> These Parties may implement such policies and measures *jointly* with other Parties and may assist other Parties in contributing to the achievement of the objective of the Convention.

Under the Kyoto Protocol, JI can only take place between Annex I countries.

Activities implemented jointly (AIJ) grew out of international negotiations on JI. It is the name given to pilot JI projects or policies undertaken collaboratively among countries to mitigate the threat of global climate change. AIJ projects do not carry carbon credits (Hirst & Fecher, 1998).

Whereas JI is only available to Annex 1 countries, the **Clean Development Mechanism** (CDM) can potentially assist developing countries as well in achieving a clean development path. More specifically, the purpose of the CDM is:

> To assist Parties not included in Annex 1 in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex 1 in achieving compliance with their quantified emission limitation and reduction commitments. (Article 12, Kyoto Protocol).

Striking differences between AIJ/JI and CDM are that:

- AIJ involves bilateral activity, whereas CDM is likely to be both bilateral and multilateral;
- AIJ has no credits, whereas credits are a central feature of CDM;
- AIJ focuses on climate change, whereas CDM focuses on both emissions reduction and sustainable development (UNEP/GEF/Danida 1998).

Note that funding opportunities arising out of the Clean Development Mechanism (as well as GEF funding described below) are based on incremental upfront costs (see section 2.2.9 for a discussion of incremental costs), as opposed to incremental life-cycle costs.

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4 A sink is a process in which greenhouse gases are removed from the atmosphere. For example, growing a tree where one did not previously exist provides a new sink for CO_2 (NCCC 1998).

2.1.7 Global Environmental Facility

The **Global Environmental Facility** (GEF) is an intergovernmental organisation which acts as the financing mechanism for the implementation of UNFCCC and other global environmental agreements. It is financed by donor grants, primarily from the USA, Japan, Germany and France. The GEF provides dedicated grants and low-interest loans to developing countries to cover the additional or *incremental* costs of investments that have global environmental benefits, but are more expensive than the cheapest alternatives. Since ratifying the UNFCCC in 1997, South Africa has become eligible for GEF funding.

2.2 Economic concepts

2.2.1 Economic costs and financial costs

Economic cost (or economic opportunity cost) is the *ideal* cost concept for use in climate change assessment. It measures the value of resources in terms of the value of the alternative uses for those resources. Economic cost is closely related to social cost (discussed in section 2.2.8 below).

Economic cost is not necessarily equal to **financial cost**. Take for instance the cost of sequestering carbon by growing trees on a tract of public land. In estimating the costs of such a programme, what do we take as the cost of the land? In some cases no financial cost is attached, because the land is not rented out and no money flows from the project implementor to the owner (the state in this case). This, however, is inaccurate in economic terms. The cost of the land is to be measured in terms of the value of the output that would have been received from that land had it not been used for forestry (UNEP 1994).

The financial cost is an important component of each project or programme. It will differ from the economic cost of a projects and programmes in the following respects (IPCC 1997). Economic costs:

- Include most external effects;
- Exclude taxes and subsidies;
- Exclude depreciation and interest payments
- Allow for a divergence between the economic opportunity costs and the market price.

Given the limitations on data and time for the Country Study, it will not be possible to use full economic costs in the analysis. Some adjustments are possible and necessary, however, to give an accurate picture of the costs of mitigation.

Sectoral assessments should be based on analyses that that include private costs but exclude external costs and benefits, and exclude taxes, subsidies, depreciation and interest payments.

2.2.2 Cost benefit-analysis

In the section above, it was recommended that sectoral assessments are based on analyses which exclude external costs and benefits, exclude taxes and subsidies but include private costs. This is not to say that analysts will only do financial analysis. Rather, sectoral analysts should undertake an economic analysis, but one which does not include external costs (see also section 2.2.8 below).

The cost concepts identified in this section of the report are defined on the basis of cost-benefit analysis, the aim of which is to measure project impacts in comparable units. It should be noted that cost-benefit analysis is not a single technique but, rather, an approach that provides a rational framework for project choice.

Traditional cost-benefit analysis measures all negative and positive project impacts in the form of monetary costs and benefits. Market prices are used as the basic valuation as long as markets can be assumed to reflect 'real' resource scarcities.[5]

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5 Where this is not the case, shadow prices could be used (see section 2.4.6).

Cost-effectiveness analysis is a specialised version of traditional cost-benefit analysis. All costs of a portfolio of projects are assessed in relation to a policy goal that represents the benefits of the projects, and all other impacts measured as positive or negative costs. The policy goal can be, for example, a specified goal of emission reductions for GHGs and other emissions. The result of the analysis can then be expressed as the costs (R/ton) of GHG emissions reduction.

Finally, **multi-criteria analysis** defines a framework for integrating different decision parameters and values in a quantitative analysis without assigning monetary values to all parameters. Examples of parameters that can be difficult to measure are human health impacts, equity, and irreversible environmental damages.

Analysts conduct cost-effectiveness analyses where the costs of meeting alternative emission reduction targets (in Rands/ton of GHG emissions) are assessed. The cost assessment framework detailed in this report indicates how such a cost-effectiveness analysis can be conducted. Non-monetary and qualitative factors should be discussed as per "Criteria for evaluating mitigation options" and "Instructions to sectoral project leaders"

2.2.3 Discounting

Discounting refers to a process that allows for comparison between the value of economic resources at different points in time. The **discount rate** refers to the rate at which discounting is undertaken. A low discount rate would place a more equal weight on future costs and benefits, as opposed to a high discount rate, which would give greater weight to costs and benefits occurring in the short term than to those occurring in the long term. Since GHG mitigation and adaptation costs studies involve comparisons over long periods of time, the discount rate is an extremely important parameter in economic calculations.

The **financial discount rate** is a market-related rate which reflects the cost of funding (often a weighted average of a required rate of return on equity capital and interest rate on loans), uncertainties and risks. The **economic discount rate** should relate to the opportunity cost of capital, or the potential returns on other possible investments.

Given that it is recommended that sectoral assessments are based on a cost-effectiveness analysis, it is further recommended that an economic discount rate is used.

Constant or real prices must be used in the cost-effectiveness analysis (see section 2.3.6 below). *It follows that in calculating the NPV for the cost-effectiveness analysis, a real discount rate (i.e. a rate that excludes inflation) should be utilised.* Here the analyst is concerned about the real return on the project.[6]

2.2.4 Nominal (or current) prices versus real (or constant) prices

A Rand does not buy as much as it did a year ago. In other words, **current** 1999 prices do not necessarily equate with the prices paid for the same product or service in 1998 prices. The price differential can be made up of two different price movements. The first relates to nominal price changes i.e. reflected by **inflation**. The economy-wide **rate of inflation** is defined as the rate of change of the overall price level and is measured as follows:

$$\text{Rate of inflation (year t)} = 100^*[(\text{price level}_{\text{year t}} - \text{price level}_{\text{year t-1}})/\text{price level}_{\text{year t-1}}]$$

The second category of price movement relates to changes in **real** prices. The real value of an item can be calculated by dividing the current value of the item by the price (or inflation) index (see below) related to a **base year**. This procedure will preserve any relative price changes, i.e. real prices fluctuations, while removing nominal price fluctuations (caused by inflation). These real price changes must be considered in the cost-effectiveness analysis.

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6 Note that the net present value of a cash flow expressed in nominal terms and discounted using the nominal discount rate will be exactly the same as the net present value of a cash flow expressed in real terms and discounted using a real discount rate.

To compare cash flows occurring in different time periods, economists have developed **price indexes,** or measures of the level of prices. The most commonly used price indexes are the consumer price index (CPI), the producer price index or deflators. For the Country Study, all prices should be reported in 1997 Rands. It is recommended that a deflator derived from Gross Value Added national accounts is used in the sectoral assessments to inflate/deflate historical prices to 1997 constant prices. See section 3.4 for recommended data, and Appendix B for a explanation of the deflator recommended.

Table 2 below gives an example of removing the effects of nominal price changes/inflation. The nominal and real price of a product costing R1000 in the first year is shown for each future year.

Year	1	2	3	4	5
Nominal price index	100	115	130	145	150
Assumed inflation	N/a	10%	10%	7%	9%
Real changes	N/a	5%	3%	4%	-5%
Current prices	1000	1150	1300	1450	1500
Constant prices	1000	1045	1074	1120	1063

Table 2: Example of removing the effects of nominal price changes

Cost-effectiveness analysis should be conducted in real or constant terms (i.e. with the effects of inflation removed).

2.2.5 Present value and Net present value

Present value (PV) is the value today of a future cash flow. This is the cash value today that is the equivalent value to a stream of cash flows occurring in the future. Net present value (NPV) refers to the present value of all positive cash flows (benefits) less the present value of all negative cash flows (costs), including any initial costs for a project.[7]

For a single future flow, FV, the present value PV is defined by:

PV = FV*PWF [Equation 1]

where:

PV = present value in base year

FV = future value in year of occurrence.

PWF = Present Worth Factor = $1/(1 + r)^t$

r = discount rate

T = time between today and the future payment

For example, if a payment is R500 is made on December 31 in the year 2002, and the discount rate is 5 % per year, then the present worth on January 1999 (4 years earlier) would be:

$PV = R500*[1/(1 + 0.05)^4] = R\ 411.35$

2.2.6 Life-cycle cost

The life cycle cost (LCC) is the total discounted (present value) cash flow for an investment with future costs during its economic life. In other words, the life cycle cost is the *present value* of all the costs associated with an investment. It generally includes the initial capital cost, the sum of

[7] The internal rate of return is the equivalent discount rate (r) at which the NPV is zero. The higher the IRR, the more cost-effective the investment.

discounted annual maintenance and operating cost, and a credit for any salvage value for the investment at the end of the project. The formula for LCC is as follows:

$LCC = C_c + \Sigma[C_n/(1+r)^n] - SV/(1+r)^t$ [Equation 2]

Where:

C_c = Initial capital cost (capital, labour, administration cost)

C_n = Operating cost (operation, and maintenance cost, fuel, tax and interest) in year *n*

SV = Salvage value (in year *t*)

For example, assume that a piece of equipment costs R1 000 to purchase and has an annual operating cost of R100/year. At the end of 8 years, the equipment is sold for R300. If the discount rate is 7 per cent, then the LCC is as follows:

LCC = R1 000 + (100/0.16747) – (R300*0.5820) = R1 423.

If the annual costs were not constant, then we would have to discount the value in each year by the appropriate present worth factor (see previous section), and then add them together. Life cycle costs would also include any implementation or overhead costs associated with projects.

To evaluate the cost-effectiveness for mitigation options, analysts should first calculate the present value of all costs in the baseline case (ie the reference case against which mitigation options will be compared) and for the mitigation project. For both, the real discount rate should be used as indicated in section 4.4. These present value costs will then be levelised as described in section 2.2.7.

2.2.7 Levelised costs

The concept of a **levelised cost** is recommended as a standard for comparison of cash flows which occur at different points in time. Levelisation involves calculating a stream of equal cash flows whose net present value is equal to that of a given stream of variable cash flows. The purpose of using levelised costs is to be able to show in equivalent annual costs of an investment, as opposed to the total costs over the life. This is important if we want to compare annual costs with annual emissions savings. The method consists of the following two steps:[8]

(i) Calculating the present value of all costs associated with an investment, O&M and fuel costs over the period from the first year of the investment to the end of the scenario period, *n* years; See section 4.4 for the discount rate, *r*, that should be used. In other words, calculating the life cycle cost of the investment.

(ii) Transforming the present value/life cycle cost to a series of equal annual payments for the period covering the first year of operation to the last year in the scenario to give the levelised cost, *LC*.

$LC = LCC \times (r/(1-(1+r)^{-n}))$ [Equation 3]

Where;

LC = levelised cost

LCC = life cycle cost of investment

r = discount rate

n = number of periods in the life of the investment (years)

If the lifetime of the investment is longer than the scenario period, a salvage value (ie the residual value of the investment) should be assumed for the last scenario year. This terminal value should be transformed to PV in the initial year of the investment and subtracted from the

[8] Most commercial spreadsheet packages have standard formulae that allow for easy calculation of NPV, IRR, levelised costs, annuities and related concepts.

PV of the investment. If the lifetime is shorter than the scenario period, it should be assumed that the technology is replaced (UNEP, 1994).

For the cost effectiveness analysis, analysts should levelise the life cycle costs of the baseline case and the mitigation option, to get an equivalent annual cost for each case (see section 4.4.4 for the appropriate discount rate to use).

2.2.8 Private, external and social costs

The costs that individual firms or households use to make decisions are called **private costs**, because they only impact the individual actors involved. The term **external cost**, on the other hand, is used to define the costs arising from any human activity that is not accounted for in the market pricing system.[9] For example, emissions of particulates from a power station affect the health of people in the vicinity, but there is no market in which impacts are valued or priced. Hence such a phenomenon is referred to as an externality and the costs it imposes are referred to as the external costs. These external costs are distinct from the internalised costs that the emitters of the particulates do incur in producing their outputs, such as the prices of fuel, labour, transportation and energy – or even mandated emissions control measures. The total cost to society is made up of both the external cost and the private cost, and together they are defined as the **social cost**.

Social cost = external cost + private cost

Ideally, estimation of mitigation and adaptation costs utilise social costs. If a mitigation option were to reduce the combustion of coal, for example, then in addition to any private benefits to the investors, the reduction in air pollution should also count as a credit to the project. Often, however, the data will only provide information on the private cost. Given data and budgetary limitations for the Country Study, most of these external impacts will only be captured in the non-economic criteria for mitigation projects (see document "Criteria for evaluating mitigation options").

Given the scope of this project, it is recommended that analysts do not include external costs and benefits associated with GHG mitigation in the sectoral assessment. In other words, analysts should undertake a cost-effectiveness analysis that only utilises easily quantifiable costs and benefits..

2.2.9 Incremental costs

Incremental cost is defined as the additional cost a country incurs when undertaking a climate mitigation project, compared with the economic cost of the activity the project substitutes.[10] In order to estimate such a cost it is necessary to identify the economic costs the country would incur in the absence of the programme or, in other words, to define the costs of the baseline scenario. Note that incremental costs can be positive or negative (reflecting an incremental *benefit* in the latter case).

Generally in the climate change literature, particularly relating to financing climate-friendly projects in developing countries, incremental costs refers to additional *up-front costs* rather than higher life cycle costs. An example would be an energy efficient lighting programme, where the initial costs of the efficient lamps could be considerably higher than for incandescent lamps, even though the life cycle costs of using energy efficient bulbs could be lower.

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9 The same logic applies in the case of benefits.

10 This is the definition adopted by the Framework Convention on Climate Change (FCCC). The FCCC distinguishes between *full agreed incremental cost* and *agreed incremental cost*. The former refers to costs incurred in situations where the project is a new activity that does not replace ongoing activities (e.g. preparing national reports to the FCCC). The latter is the relevant concept when the project replaces other activities which would have happened in the absence of the FCCC (UNEP 1994).

The incremental cost is one of the key concepts in the UNFCCC. The methodological framework that has been suggested in this report defines economic cost concepts (and an analytical structure) that are generally consistent with this concept.

2.2.10 Implementation costs

In traditional cost-benefit analysis, implementation costs are assumed to include short-term costs such as the cost of planning activities, administration, information, training, monitoring and the like. These costs are usually termed **administration costs**. Successful implementation of large-scale environmental projects or strategies such as climate change mitigation strategies will, however, typically involve costs that exceed administration and training costs. The existence, for example, of market imperfections, imperfect information, institutional failures, external costs, ill-defined and/or poorly enforced property rights, indicate that implementation may not be a smooth process.

Implementation can then be supported by specific measures to remove and reduce market barriers in order to realise the desired outcome of a given project or strategy. These additional measures can be termed **barrier removal measures**, and the analogous costs are called barrier removal costs. They are incurred to reduce the social costs in the longer run by making regulation and policy instruments work, and are generally time and context specific. Examples of such costs include the costs of:

- improving institutional capacity;
- reducing risk and uncertainty;
- enhancing market transactions; and
- enforcing regulatory policies.

Analysts should take account of implementation costs where possible in the life cycle costs calculations.

2.2.11 Change in unit cost of production

For the purposes of translating individual mitigation options into scenarios for macroeconomic analysis, it is important to understand how mitigation projects could affect the cost of production in a given sector. If the mitigation project has both an initial capital cost and increasing running costs, for example, clearly it will increase that company or industry's cost of production. If an initial investment leads to longer term savings, however, the cost of production could decline.

The concept of levelised cost can help assess what the change in unit cost of production will be. The levelised cost in the baseline scenario should reflect the current cost of structure in the industry. If the levelised cost of the mitigation option is higher than in the baseline case, then the cost of production has increased.

Take the example of replacing constant speed motors within a steel plant with more energy efficient variable speed motors. We would first calculate the life cycle costs of operating a constant speed motor – ie the capital cost of the motor plus the discounted future operating costs (see Equation 2). We would then do the same for the variable speed motor system, where the initial cost might be higher but the operating costs would be lower. Then we would levelised both of these values (see Equation 3).

Now the question is how to relate this to steel production. Let us say that in this case the levelised cost of the constant speed motor is 100 R per year, while for the variable speed drive is 80 R per year. If the mitigation project was to replace 100 motors in a plant that produce 80 tons of steel per year, then the change in production cost is as follows:

$$\text{Change in production cost} = (LC_M - LC_B) \times \text{number of sites} \qquad \text{[Equation 4]}$$

LC_B = levelised cost for baseline

LC_M = levelised cost for mitigation

In this example,

Change in production cost = (R80 – R100) x 100 sites = R-2000

If output was 80 tons in the that year, then the change in unit production cost for that facility is,

Change in unit production cost = change in prouduction cost / units production

[Equation 5]

Change in unit production cost = R-2000/80 tons = R-25/ton

In other words, the cost of production has fallen by 25 R/ton. Note that this change in unit production cost is *only for this facility*, not for the entire industry (unless the mitigation project covers the whole industry). Only that portion of the sector's production that if from this facility will be affected.

2.2.12 Shadow pricing

This section provides an explanation of an economic concept that, while it is important for the analysts to understand, will not actually be used in the Country Study analysis. The explanation is provided, rather, as background in case analysts come across references to shadow prices in their literature reviews on mitigation options.

As noted above, the ideal cost to use to consider GHG projects is one based on economic opportunity cost. Where markets operate competitively and efficiently, the market prices will accurately reflect the economic cost. Where there are market failures, however, market prices may not be a good indication of opportunity costs.

An important example of **shadow pricing** revolves around the cost of labour. In a context of high unemployment, such as in South Africa, wage rates often do not correctly reflect the relative scarcity/abundance of labour, one reason being the greater bargaining power exercised by employed workers as opposed to unemployed people. In this context, true economic value of a market wage may be lower. The lower figure should be the shadow wage rate and, if used in comparing two projects with the same quantity of labour inputs, would tend to favour the project in which the shadow wage rate is used to value labour costs. Adjustments to market prices to obtain shadow prices will be needed when:

- there are distortionary taxes and subsidies, so market prices deviate from economic opportunity costs;
- there are monopolies and other market imperfections making the market price higher or lower than the shadow price.

Areas where analysts typically use shadow pricing include the following:

- *Unskilled labour*. In an ideal market, the labour wage rate should be equal to the value of its marginal product of labour – that is, the wage should be equal to the additional production that one additional labourer could produce. In South Africa, where there is a high unemployment rate, the opportunity cost of labour is low – that is, if labour were not employed by the project, the opportunities for employment elsewhere would be limited. The shadow wage of labour should thus be estimated by the potential productivity of labour in alternative activities. Generally it would only be appropriate to apply shadow wage rates to unskilled labour. For semi-skilled and skilled labour, it is likely that alternative employment would be found without the project. In these cases it is likely that the actual wage is an accurate reflection of the opportunity cost of their labour. (Davis & Horvei 1995).
- *Foreign exchange*. Where there are wide-ranging import restrictions, foreign exchange controls and no or limited currency convertibility, the official exchange rate may not reflect the true value of foreign exchange to the economy. A shadow exchange rate can be used to correct for this. The shadow price can be determined as an index of import and export

prices to reflect the value of substituted imports by allocating foreign exchange to mitigation activities (UNEP 1998).

- *Capital markets*: Again, due to market imperfections it may be necessary to adjust the price of certain capital items to reflect their true economic cost. A shadow price can be based on the marginal return on capital in the private sector. This reflects the return foregone in the private sector by demanding capital for use in climate change mitigation activities.

It is recommended that sectoral analysts do not utilise shadow prices for labour, exchange rates and capital. The information available on this is sub-sector specific and difficult to obtain. Sector analysts should therefore use market prices for labour, exchange rates and capital.

3. Overall methodological approach to sectoral assessments

This section outlines the overall approach to the sectoral assessments. Each major step in the process in described, while sections 5 and 6 of this report present more detail on assessing individual mitigation project options.

3.1 A five-step approach

This approach comprises the following steps: (i) constructing the baseline scenario; (ii) identifying mitigation options; (iii) assessing mitigation potential and costs of options; (iv) constructing mitigation scenarios; and (v) undertaking a sensitivity analysis.

3.1.1 Step 1: Constructing a baseline scenario

Mitigation assessments should consider the impacts of implementing climate change mitigation strategies in relation to a baseline projection in which there are no policies in place designed explicitly to reduce GHG emissions. In other words, the baseline analysis should be strictly limited to the present characteristics of economic development and technical systems.

Baseline scenarios should seek to include long-term scenario assumptions such as economic growth, population growth, urbanisation, land-use changes, infrastructural investments and development of the economy (IPCC 1996b). Baseline scenarios should reflect national development priorities in South Africa. In addition, the baseline scenario should include where possible the impact of climate change on climate sensitive sectors in which mitigation takes place. This is because both emissions reductions and the costs of mitigation can depend on the impacts of climate change. This is especially true for the forestry and land-use sectors, the agricultural sector and the energy sector (UNEP 1998).

Because the mitigation assessments consider individual projects, and sector strategies, baseline definitions should also be defined in accordance with these aggregation levels i.e. project and sector. Each sector analyst will construct a baseline scenario for their sector.

When constructing sectoral baseline projections, analysts should take account of any autonomous technological and behavioural change that is occurring, or has the potential to take place in the sector – that is, change that would potentially have occurred even without any mitigation policy. Such change could be induced by technological improvements, behavioural change, resource scarcity, or other economic and social factors.[11]

For the agricultural sector, for example, constructing baseline scenario(s) involves projecting, over time, the agricultural activities that will be affected by potential mitigation options. The

[11] In the energy sector, where efficiency and other technological improvements occur frequently, autonomous change is referred to as *autonomous energy efficiency increase* (AEEI).

baseline cases have two components. First, they describe a general scenario of agricultural sector development and the GHG emissions that would occur from various sources in the absence of specific measures to mitigate climate change. This scenario of agricultural development should be closely tied to general macroeconomic trends projected for the country, as well as national development plans related to agriculture. Secondly, they describe the physical parameters of the agricultural sector activities that will be displaced by the mitigation option, the GHG emissions and carbon sequestration fluxes associated with these activities, and their cost components. Once the baseline cases are established, they serve as the basis for evaluating the effects of the mitigation options. Once relevant future agricultural activities (such as number of livestock, fertiliser use etc) have been projected, these estimates can be used as inputs for estimating the associated annual GHG emissions and soil carbon fluxes. This involves determining:

- the future demand for agricultural products that are associated with specific types of GHG emissions;
- the level of output and area allocated to the production of these products;
- the production systems/management methods associated with producing these crops;
- the input use for resources that will be affected by the mitigation measure, directly or indirectly, and
- the demand for fuel that will compete with mitigation options that produce a substitute fuel.

In addition, information is needed about the costs and benefits associated with the production activities that will be displaced or affected by the mitigation options. This includes information about direct fixed and variable costs associated with different production systems for each product, the revenues from production, and the net returns per unit area (or per unit product). Where the mitigation option involves substitution/displacement of nutrient sources or alternative fuels, this type of information needs to be supplemented with additional information about fertiliser and fuel demand and input prices in order to determine the cost effectiveness of the proposed measures with reference to the baseline case. Thus, constructing the baseline scenarios for the agricultural sector will depend on the mitigation measures that will be selected in the third step of this approach.

Because constructing baseline scenarios involves projecting base case activities in the future, some modelling will invariably be required. The baseline scenario for the energy sector, for example, includes projections of future energy demand and supply system structure. Energy demand projects can either be closely linked to macroeconomic activity projections or can be based on detailed inventories of energy consuming technologies – that is, a bottom-up approach. The supply system projections are closely linked to different energy modelling approaches. The main distinction here should be made between energy **optimisation models** (e.g. MARKAL) that project future technologies as the least cost future technology choice and **simulation models** (e.g. LEAP) that project future supply technologies as a development trend from the present system structure (UNEP 1998).

In line with the nature of the baseline scenarios recommended earlier, it is suggested that a bottom-up simulation model (probably LEAP) is used by analysts.

3.1.2 Step 2: Identifying mitigation options (including technology and policy options)

A large number of technologies can in principle be assessed as part of a mitigation scenario, but only a limited number of these options will be important in a South African context. Examples of mitigation options associated with the most important future sources and sinks for different sectors could be as follows:

Energy

- end-use efficiency improvements in household, industry, service sectors;
- transmission systems;

- fuel substitution;
- renewable technologies (decentralised);
- supply technologies (centralised): fossil fuels, nuclear and renewable.

Agriculture

- fertiliser control schemes;
- introduction of crops with enlarged carbon sequestration capability;
- livestock management: manure treatment, feeding.

Forestry

- afforestation projects;
- increasing the carbon sequestration capability of growing forests (increasing biomass density);
- recycling or permanent storage of carbon sequestered in harvested biomass;
- reforestation.

Transportation

- efficiency improvements for vehicles;
- switch to fuel systems with lower emissions;
- improved transport system efficiency;
- modal shifts;
- managed transport demand.

Industry

- improved cement production;
- improved aluminium production.

While this report is primarily concerned with the costing methodology for mitigation options, sectoral analysts will also need to collect information about a range of other issues such as: consistency with national policy goals, ease of implementation, and a variety of sector specific characteristics. For these criteria, analysts should consult "Criteria for evaluating mitigation options". Because data collection is very time consuming, a screening process should therefore be carried out to select those options which will be assessed in the third step.

3.1.3 Step 3: Assessing mitigation potential and costs of options

Mitigation assessments should consider:

- individual projects and sector strategies (national assessment will be a separate piece of work)
- reduction potential and cost of mitigation options.

This step will require extensive collection of detailed technical information and sample data. In this regard, no primary research should be undertaken by sectoral analysts: assessments should be based on existing information. Detailed descriptions of cost data and calculations are contained in sections 5 and 6 of this report.

For the forestry sector, for example, this step involves estimating the carbon reduction potential (sourced in trees, soil, forest floor, understory vegetation), as well as the costs of the different mitigation options with reference to the baseline scenario. Costs that should be included are land conversion and establishment costs, maintenance costs, harvest costs and revenues, and the opportunity cost of the land.

The cost calculations for all mitigation assessments should use the basic concepts and methodologies defined in section 2 as well as the parameters recommended in section 4.

3.1.4 Step 4: Constructing a mitigation scenario

One way of presenting the mitigation scenario results is to use **GHG emission reduction marginal cost curves**. These marginal cost curves can, in some cases, be created using just information about emission reductions and project outlays on individual projects. In other cases, the marginal cost curves should be constructed, in ranking order, on the basis of integrated sectoral assessments. Marginal cost curves for every sectoral assessment should appear in ranking cost (per reduction in GHG) order. Least cost combinations would then be assimilated into a cross-sectoral assessment, which as noted will be undertaken as a separate component of the Climate Change Country Study.

The GHG emissions reduction marginal cost curve expresses the relationship between the minimum cost to society of reducing an additional ton of GHG emissions and the corresponding level of emissions reductions. GHG emission reductions are defined as reductions in relation to the baseline.

The emissions reduction targets can either be defined in relation to a base year (i.e. 1990 emissions) or in relation to future baseline scenario emissions. Figure 1 shows these alternative definitions of emission reduction targets. Line A illustrates future baseline emissions, line C corresponds to the base year emission level while line B represents a reduction scenario. For this mitigation option, therefore, emissions would be reduced relative to the future projected baseline, but not in relation to emissions in the base year. Clearly, therefore, it is preferable to assess emissions reductions in relation to future projected baselines.

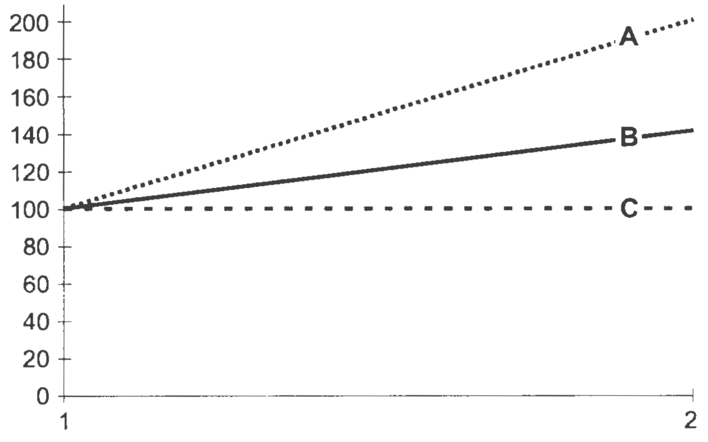

Figure 1: GHG emission scenario cases
Source: UNEP Collaborating Centre on Energy and Environment (1998)

All mitigation options should be assessed relative to the relevant sectoral future baseline scenario, not current emissions.

An example of the cost curves for the energy sector as estimated in the UNEP format is shown in Figure 2 below. This cost curve is a comparison of marginal reduction cost for CO_2 reduction in the long term assessed for the countries participating in the UNEP study. CO_2 reduction is measured in percentage of future baseline scenarios, and costs are measured as levelised costs of emissions reduction.

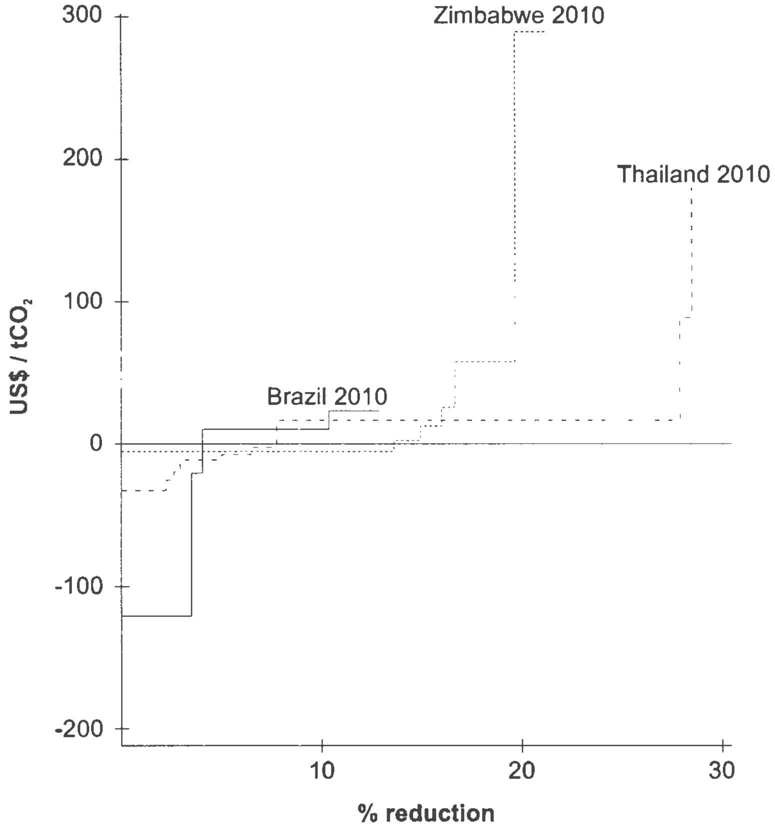

Figure 2: Marginal cost curves of GHG emission reduction (UNEP country studies)

Source: UNEP Collaborating Centre on Energy and Environment (1998)

These curves are constructed by ranking mitigation options by their cost of abatement, and then making their width on the chart correspond to either relative or total emissions reductions. The stepwise calculation of reduction cost is illustrated in Figure 3 below. The total reduction costs can then be calculated as the area under the marginal abatement cost curve.

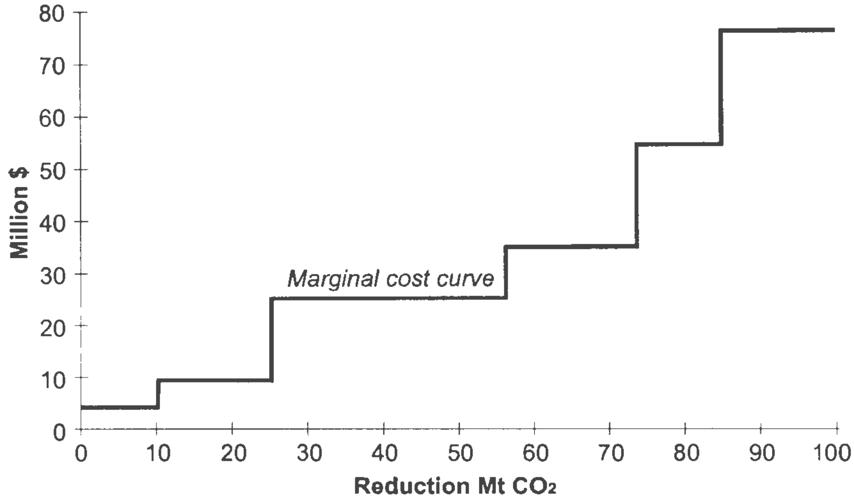

Figure 3: Marginal cost curves of GHG remission reduction
Source: UNEP Collaborating Centre of Energy and Environment (1998)

3.1.5 Step 5: Sensitivity analysis

Financial and economic analysis rests on a number of assumptions and predictions. Estimates of costs, demand, prices and other parameters are approximate, even for the present, and the uncertainty will increase where these estimates are projected in the future. As a starting point, care should be taken to ensure that the baseline scenario incorporates the best estimates of the sectoral analysts and previous research in the sector. Attempts should be made to eliminate biases since this distorts the comparison of alternative projects. Since actual values may deviate from these estimates, it is important to investigate the impact of such deviations on the NPV of the project.

Sensitivity analysis is a method that takes each of the important variables and, singly or in combinations, varies the magnitude to determine how sensitive the result is to such changes. The results of the sensitivity analysis help to provide an understanding of the critical elements on which the outcome of the project depends. It may identify the variables where additional attention is required in refining the original estimates. It may also aid project management by identifying areas of the projects that will require close monitoring and supervision (Davis & Horvei, 1995).

To undertake a sensitivity analysis, project analysts should:

- Identify key generic and sector specific variables where uncertainty rests (for example, discount rate, technology cost, project duration etc.)
- Establish a reasonable range of uncertainty (for example 3 to 9 per cent for real discount rate)
- Calculate how the cost effectiveness of the intervention changes, in R/ton CO_2 equivalent, when the input variable changes

Sector analysts should conduct sensitivity analyses of each sectoral assessment undertaken. Project analysts should undertake sensitivity assessments for a reasonable range of discount rates (recommended: 3 % and 9 %), as well as for other sector specific variables where there is a risk that the value may change or fluctuate (i.e. for technology costs or other background parameters).

3.2 Non-monetary and qualitative impacts

Impacts that can not be readily converted into monetary units (even if they are quantitative) and qualitative impacts will be considered in the document "Criteria for evaluating mitigation options". This report only deals with monetary impacts.

3.3 Identifying limitations of the analysis

Assessments undertaken for this project will the first of a series of assessments undertaken by South African analysts as part of South Africa's commitment to reducing its GHG emissions. In this context, *it is recommended that each sectoral assessment should be presented together with a brief commentary on the limitations and strengths of the assessment undertaken.* This commentary could include limitations and strengths of:

- the project's organisational structure;
- the methodology of the assessment;
- the research environment (i.e. data availability, value of data etc);
- other limitations/barriers encountered.

Recommendations for future studies of this nature (or how to improve on the current study) should also be presented.

4. Recommended parameters

4.1 Introduction

National climate change mitigation assessments examine the impacts of implementing alternative projects and policies in relation to future GHG emission sources and sinks. This implies that the assessment must include assumptions on future development trends in GHG emissions, technology and policy options and on the impacts of implementing these options. Each country study should use the same core assumptions, inputs and outputs in developing the baseline and GHG emissions reductions scenarios and their associated projections, but not necessarily the same parameters. This section of the protocol recommends parameters for the studies.

4.2 Scenario assumptions

Studies should not try to be exhaustive in the selection of mitigation projects in the sectors or across sectors, but should rather focus on projects relating to the most important national sources and sinks. Broadly, options considered for inclusion in the assessment should consider cost-effectiveness, emissions reductions, sustainability, employment, income and poverty and/or environmental considerations

For now, mitigation assessments should focus on the assessments of selected individual mitigation projects for sectors where the mitigation effort can be expected to have significant impacts. Once sectoral studies are underway it is recommended that mitigation ranges (ie what level of emissions reduction) are identified, reported and that more specific ranges are agreed.

4.3 Environmental parameters

4.3.1 Emission factors

For a comprehensive list of emission factors, sectoral analysts should refer to IPCC (1997) guidelines and the South African Greenhouse Gas Emissions Inventory.

4.3.2 Global warming potentials

Table 3 below notes standard Global Warming Potentials of various gases as defined by the IPCC (1995a). Where relevant, South African assessments should utilise this data.

Species	***Chemical formula***	***100 years GWP***
Methane	CH_4	21
Nitrous oxide	N_20	310
Perflouromethane	CF_4	6 500
Perflouroethane	C_2F_6	9 200
Perflourobutane	C_4F_{10}	7 000
Sulphur Hexaflouride *HFC-23	SF_6	23 900
HFC-32		
HFC-43-10	CHF_3	11 700
HFC-125	CH_2F_2	650
HFC-134a	$C_5H_2F_{10}$	1 300
HFC-143a	C_2HF_2	2 800
HFC-152a	CH_2FCF_3	1 300
HFC-227ea	$C_2H_3F_3$	3 800
HFC-236fa	$C_2H_4F_2$	140
HFC-245ca	C_3HF_7	2 900
	$C_3H_2F_6$	6 300

	$C_3H_3F_5$	560

Table 3: Global Warming Potentials (100 years time horizon)
Source: UNEP Collaborating Centre on Energy and Environment (1999)

To convert non-CO_2 emissions to their CO_2 equivalents, multiply weights defined by the Global Warming Potentials by sector specific emissions (taken from IPCC default values). Sum various emissions together if necessary to get a total CO_2 equivalent for the reduction option.

	Emissions reductions (tons)	GWP	Emissions reductions (CO2 equivalent)
Fuel CO_2 emissions	200	1	200
Fuel CH_4 emission	2	21	42
Fuel N_2O emission	1	310	310
Total CO_2 equivalent			552

Table 4: Example of converting non-CO_2 emissions to their CO_2 equivalents

4.4 Economic data

In this section, baseline historical and some projected data for economic growth, inflation rates, exchange rates, and population growth are given.

Note that the parameters outlined below are:

- broad, in that they could be applied by analysts to all assessments. These parameters are not exhaustive: clearly, specific sectoral studies will require more specific data in addition to the parameters presented here. The energy sector assessment(s), for example, will have data for energy demand (structural change and technological change), energy supply (technology availability and cost), price and income elasticities of energy demand, fuel and appliance efficiencies, existing tax systems and tax recycling, implementation issues (such as instruments and barriers) and so on.
- suggestions to the project leaders on what data to use. All values must be reviewed by a workshop before being finalised.

4.4.1 GVA nominal, GVA real, GVA growth, GVA deflator and inflation rate

The appropriate *inflation* index is based on overall growth in economic output. See Appendix B for a detailed explanation of Gross Value Added and its uses. By multiplying prices from a given year by the conversion factor in column 6, they will be expressed in 1997 Rands. For example R100 in 1990 is equivalent to R210 (100* 2.10) in 1997.

Note that this index should only be used by sectoral project leader to convert prices from years other than 1997 into 1997 prices. It does not replace the GDP estimates or projections from the macroeconomic assessment conducted by IDC. No projections of inflation are given because all mitigation analysis should be done in real Rands (ie net of expected inflation). IDC will provide GDP growth projections, not this document.

	(0)	**(I)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Year	**GDP nominal R million**	**GVA nominal R million**	**GVA real R million (1995 constant prices)**	**GVA growth**	**GVA deflator**	**Inflation rate**	**Conversion factor to 1997 prices**
1988	209 613	194 192	473 121		41.04		2.84
1989	251 676	231 012	484 728	2.45	47.66	16.11	2.45
1990	289 816	266 783	481 077	-0.75	55.46	16.36	2.10
1991	331 980	303 407	474 665	-1.12	64.56	16.41	1.81

1992	372 227	343 556	465 159	-2.22	73.95	14.56	1.58
1993	426 133	390 842	471 670	1.40	82.86	12.05	1.41
1994	482 120	440 147	485 782	2.99	90.61	9.34	1.29
1995	548 100	500 354	500 354	3.00	100.00	10.37	1.17
1996	614 942	562 503	520 786	4.08	108.01	8.01	1.08
1997	680 212	621 887	533 356	2.41	116.60	7.95	1.00
1998	737 813	673 153	536 518	0.59	125.47	7.61	0.93

Table 5: South African national accounts and inflation

Source: SA Reserve Bank Bulletin, June 1999

Notes:

1. GVA growth is, for example, 100*(GVAreal1989 – GVAreal1988)/GVAreal1988
2. GVA deflator is 100* (2) / (1)
3. GVA-derived inflation is, for example, 100*(GVAdeflator1989-GVAdeflator1988)/GVAdeflator1988

4.4.2 Exchange rates

Year	R/$ exchange rate
1988	2.2726
1989	2.6222
1990	2.5877
1991	2.7609
1992	2.8516
1993	3.2667
1994	3.5497
1995	3.627
1996	4.2964
1997	4.6073
1998	5.5316

Table 6: Average annual exchange rate
Source: SA Reserve Bank Quarterly Bulletin, June 1999

4.4.3 Demographic data

Year	Population ('000)	Population growth
1991	36 199	
1992	36 992	2.2 %
1993	37 802	2.18 %
1994	38 631	2.12 %
1995	39 477	2.2 %
1996	40 342	2.14 %
1997	41 227	2.19 %
1998	42 131	2.14 %

Table 7: South African population
Source: Statistics SA, Statistical release PO302,
17 December 1998, Table 1. 1988-1990 data unavailable.

Years	Projected annual population growth rates
1999-2015	1.92 %

2015-2030	1.06 %

Table 8: Project annual population growth

Source: 1999-2015 IDC Model; 2015-2030 based on Business Futures 1998 (Roux 1998).

Factor	Data		Source
Urbanisation	54 per cent urban 46 per cent non-urban		CSS 1996 census
Number of people per dwelling	1 489 890	1	CSS 1996 census
	1 572 466	2	
	1 324 325	3	
	1 373 989	4	
	1 075 272	5	
	757 445	6	
	510 822	7	
	343 522	8	
	359 991	9	
	255 839	10+	
Total number of dwellings	9 059 571		CSS 1996 census

Table 9: Other relevant demographic data

Source: Statistics SA, 1996 Census.
NB: Future urban/rural split not available in published projections

4.4.4 Other economic parameters

Factor	Parameter	Comment	Source
Price indexes	1997 Rand (real)	All time series should be converted to this year using the conversion factor provided in Table 5.	Standard for South Africa Country Study; Reserve Bank
Discount rate	6% (real)	If the market rate, assumed to be 15% to reflect an average 1997 rate, is adjusted for inflation, the real rate would be approximately 7- 8%. The Reserve Bank typically recommends social discount rates of 6-8%, and other country studies have typically used on the order of 6% *Sensitivity analyses could be carried out for real discount rates of 3% and 9%.*	CSIR, Reserve Bank, UNEP
International oil price	$18 (1997)	The long term trend in oil prices is assumed to rise slowly in real terms reaching about $23 a barrel in 2020 relative to 1997 prices	Energy Outlook (1998)

Table 10: Other recommended economic parameters

NB: Domestic fuel prices are not provided here, but in the "Instructions to Project Leaders" document.

4.5 Timeframe for analysis

The timeframe of national climate change mitigation studies must be long enough to reflect the economic lifetime of major energy supply and infrastructural investments (typically 30 – 40 years) and the long term nature of atmospheric greenhouse gas concentration (up to 100 years for CO_2). The time frame for the South Africa Country Study is 1990 to 2030.

It is recommended that sectoral analysts consider both short and long term issues when constructing baseline scenarios and mitigation scenarios..

- *Short-to-medium-term* (2000-2009). This should include a detailed assessment of main development trends in economic sectors and GHG emissions, and an assessment of mitigation options related to end use demand, production and energy supply technologies.
- *Long-term* (2000-2030). This should include an assessment of the most important long-term trends in GHG emissions including GDP growth, population, energy requirements, land-use patterns, and technological progress, assessment of mitigation options related to new advanced technologies in the energy, manufacturing and transportation sectors and to major infrastructural projects.

5. Summary of steps in assessing individual mitigation projects

The recommended steps for cost-effectiveness analysis for individual mitigation projects are described below. An example is presented in the next section.

1. Identify the mitigation option and relevant project-specific baseline (ie what would have been in place without the mitigation option)
2. Identify time frame for the mitigation option

- The time frame will depend on the nature of the mitigation option

3. Calculate the life cycle costs of the mitigation option and the business as usual option

- The recommended discount rate is 6 percent real

3a. Capital costs

- Express the capital costs in constant 1997 prices
- Exclude any sunk costs (costs that have already been incurred and would not change regardless of whether the mitigation option is implemented)
- Exclude VAT payments
- Include costs which have been covered by grants
- Convert financial values to economic equivalents, by excluding subsidies and taxes, interest payments, and depreciation

3b. Ongoing costs

- Estimate the annual maintenance and support costs for the analysis period
- Estimate the annual operating costs
- Convert financial values to economic equivalents, by excluding subsidies and taxes, interest payments, and depreciation

3c. Total life cycle costs

- Calculate life cycle costs of baseline and mitigation option using Equation 2.

4. Calculate levelised costs

- Calculate levelised costs of baseline and mitigation option using Equation 3.

5. Calculate emission savings

- For energy projects, identify energy savings (eg energy use under the baseline less energy use under the mitigation project)
- For all projects, identify GHG emissions savings (eg emissions under the baseline less emission under the mitigation project)
- Establish emission factors related to mitigation options
- Convert all emissions savings to CO_2 equivalents using relevant GWPs
- Calculate annual CO_2 equivalent savings associated with the mitigation option

6. Calculate cost-effectiveness of mitigation options

- Calculate the incremental annual costs (ie the incremental levelised costs), by subtracting the baseline levelised costs from the mitigation project levelised costs
- Divide this incremental cost by annual emissions savings to get cost effectiveness (units in R/ton CO_2 equivalent)

7. Calculate change in unit production cost

- Calculate total change in production cost using Equation 4
- Calculate change in unit production cost using Equation 5

8. Conduct a sensitivity analysis

- Identify key variables
- Generate results for discount rates from 3% to 9%
- Generate other sector specific sensitivity results

9. Describe non-quantifiable effects

- Give consideration of impacts not reflected in the cost-effectiveness analysis. Refer to "Instructions to Sectoral Leaders" and "Criteria for evaluating mitigation options".

6. Case example of individual mitigation project assessment

6.1 Energy efficiency lighting example

An example of an assessment of efficient lighting as a mitigation option is shown in this section. The lighting option is a replacement of incandescent lamps with compact fluorescent lamps. It is assumed that the lighting options are implemented in an energy system with coal based power plants with an average efficiency of 35 per cent, and 10 per cent transmission losses. The cost of the incandescent lamp is US$5 compared with US$0.60 for the reference lamp.

6.1.1 Technical and economic assumptions

The main technical and economic assumptions used in the calculation of CO2 reduction costs show in Table 11 below.

General assumptions	
Discount rate	10 %
Fuel CO2 emission factor	95 kg CO_2/GJ coal
Fuel CH_4 emission factor	0.0015 kg CH_4/GJ coal

Fuel N_2O emission factor	0.003 kg N_2O/GJ coal
Coal to electricity efficiency	35%
Electricity transmission and distribution losses	10%
Cost of electricity	US$0.10/kWh
Mitigation option:	
Overhead costs (per lamp per year)	US$1.00
Activity	1 000 locations
Cost of efficient lamp	US$5.00
Lamp lifetime	10 000 hours
Lamp wattage	15 W
Daily usage	4 hours
Annual electricity used	22 kWh/0.08 GJ
Baseline:	
Project scope	1 000 locations
Cost of incandescent lamp	US$0.60
Lamp lifetime	1 000 hours
Lamp wattage	60 W
Daily usage	4 hours
Annual bulb replacement cost	US$0.88
Annual electricity used	88 kWh/0.32 GJ

Table 11: Basic assumptions applied to the assessment of lighting mitigation option

Note that because an incandescent bulb does not last an entire year (usage of 1460 hours versus lifetime of 100 hours), the annual replacement costs are higher than the cost of an individual bulb.

6.2 Mitigation cost calculation

The mitigation cost calculations here are shown for an individual bulb. To get the total investment costs and benefits, we would simply multiply these results by the project scope (1000 installations). Note that the incremental costs in this case are negative, because the life cycle cost of the mitigation option is lower than that of the baseline.

Costs in US$	Mitigation option	Baseline	Increase (Reduction – Reference)
Project life	7	7	
Capital cost (including initial overheads)	6	0	6
Annual operating costs (electricity)	2.2	8.8	-6.6
Annual operating costs (bulb replacements)	0	0.9	-0.9
Life cycle costs	16.7	46.9	-30.2
Levelised costs	3.4	9.6	**-6.2**
Levelised costs for total programme	3400	9600	-6200

Table 12: Mitigation cost calculation

The next table shows the calculation of emissions savings for the whole project, ie for 1000 installations.

Annual emissions	Mitigation option (ton)	Baseline (ton)	Reduction
Fuel CO_2 emissions	23.8	95.1	71.3
Fuel CH_4 emissions	0.000	0.002	0.002
Fuel N_2O emissions	0.001	0.003	0.002
Total CO_2 equiv.	23.8	95.1	71.3
US$/ton CO_2 equiv.			**-87**

Table 13: Reduction in emissions

The abatement costs here have been calculated using the equations presented earlier in the text. For this option, the cost of mitigation is actually negative – on of life cycle basis we save money by investing in efficient lamps. Clearly, this will not be the case for many mitigation options.

Once similar calculations have been done for other sectoral mitigation options, the sectoral analysts should combine the information of all options into a common worksheet in order to calculate the mitigation potential and costs of the individual options. The options should be ranked according to cost effectiveness as a last step towards constructing a cost curve. An example cost curve for a GHG mitigation study in Zimbabwe is shown in Appendix C.

As can be seen in Appendix C, the Zimbabwean study included a total of 20 options. The mitigation costs and GHG reduction potential were calculated individually for all of these options. Technical interdependencies between the 20 options considered were small. This assumption seems reasonable because the options typically represent marginal changes.

7. Information sources for technology options

While it should be emphasised that there is no true substitutes for local country-specific data, there are several sources containing generic data characterising different technologies and their costs and performance which can provide a useful starting point for the South African assessments. Some of these data sources are described below (contact details are provided in Appendix A).

- IIASA CO_2 Data Bank. The CO_2 Bank, housed at the International Institute for Applied Systems Analysis in Austria, contains approximately 1 500 entries describing a wide range of technologies including energy supply- and demand-side technologies, fuel extraction and conveyance, and passenger transportation. The entries contain, with varying degrees of detail, information on energy consumption, capital costs, operations and maintenance costs, pollutant emissions, and source references. The CO_2 Bank contains significant amounts of both European and North American data as well as a limited amount of data from developing countries. It is provided free of charge as an electronic database through an interactive software programme.
- IPCC Inventory of Technologies, Methods and Practices for Reducing Emissions of Greenhouse Gases. The Intergovernmental Panel on Climate Change has produced this database as a technical appendix to the Climate Change 1995 Working Group II Second Assessment Report. The IPCC Inventory contains approximately 100 technologies, including energy supply, end-use, fuel extraction, and passenger transportation. The data is concentrated on US technologies and processes.
- Environmental Management for Power Development (EM Model). The EM Model is a computer software package and database developed by the German aid agency GTZ, the Oeko Institut, and the World Bank. The software performs environmental analysis of

energy supply technologies by analysing the full fuel chain, including fuel extraction, transportation, combustion and conversion. The software contains generic data on a wide range of technologies and processes including costs and detailed pollutant emissions.

- CEC Energy Technology Status Report. The Energy Technology Status Report (ETSR) is published by the California Energy Commission (CEC), and is a multi-volume document describing a wide variety of supply-side and end-use energy technologies and processes including coal, oil and gas combustion, nuclear, geothermal, photovoltaics, ocean energy, fuel cells, storage systems, pollution control, water heating, space heating, space cooling, lighting, appliances, boilers, motors, load management, and transmission technologies. The coverage includes qualitative descriptions of the technologies, barriers to implementation and quantitative economic analysis
- E Source. E Source is perhaps the most complete source of end-use technology data and publishes, amongst other things, five comprehensive technology atlases covering lighting, drive power, space cooling and air handling, space heating, and residential appliances. These atlases include theory, design tips and performance and cost information. E Source also publishes a variety of reports on a regular basis including recent technology developments, product reviews, application issues, case studies and newsletters.
- ACEEE. The American Council for an Energy-Efficient Economy (ACEEE) is a non-profit organisation dedicated to advancing energy efficiency as a means of promoting both economic prosperity and environmental protection. Amongst other things, ACEEE publishes a variety of books and reports and organises conferences related to energy efficiency. ACEEE publications include useful energy efficiency design guidelines through books and reports such as 'Energy-Efficient Motor Systems', 'Financing Energy Conservation', Improving Energy Efficiency in Apartment Buildings', and 'Energy Efficiency and the Pulp and Paper Industry'.
- EPRI TAG. The Electric Power Research Institute is a research organisation jointly financed by US investor-owned electric utilities. EPRI publishes a set of useful Technical Assessment Guidelines (TAG). The TAG reports provide information on electric supply-side and demand-side technologies, assessment methods and data.
- GREENTIE. GREENTIE is a project of the IEA to provide information about energy technologies. Though GREENTIE does provide some technology information, its main function at this time is a directory of companies and organisations working with the various technologies. The GREENTIE database could be useful for countries that are contemplating developing a particular technology option and are looking for technical expertise and partners in the particular technology.
- TED. The Technology and Environmental Database, from the Stockholm Environment Institute, will bring environmental, technological and cost data to those interested in national and international energy and environment analysis, greenhouse gas mitigation analysis, project screening and other forms of energy policy modelling and analysis. An earlier version of the database (DOS-based) is available currently, but a new version is currently under construction. When complete, it should provide data on environmental considerations (emissions of GHGs and other pollutants associated with the technology, land use impacts and water impacts); technical data (efficiency, availability, lifetime); costs (capital, O&M, fuel); implementation experience (market barriers, key factors in technology choice and success).
- IKARUS, FIZ-Karlesruhe. This database covers energy supply and demand technologies and makes projections of key data values. It has a European focus, is reportedly up to date, and comes with a modelling tool for carbon analyses.
- DECADES, IAEA. This database, not yet available, comprises extensive coverage of power sector technologies; looks at stages from fuel production to disposal. It has a European

focus but with associated country-specific databases which may not be available to other countries. It comes with a modelling tool.

- CADDET Register. This database contains approximately 2 000 demonstration projects on energy efficiency and renewable energy technologies. All information is case- and site-specific. Little information on developing countries is available. It is US-focused. It is continually being updated.

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Appendix A
Source details for technology databases

IIASA CO_2 Data bank
The CO_2DB is distributed free of charge to non-profit making organisations and can be obtained by sending a written request to the IIASA project leader at the following location:

Dr N. Nakicenovic
Environmentally Compatible Energy Strategies
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

IPCC Inventory of Technologies, Methods, and Practices for Reducing Emissions of GHGs
The IPCC Inventory can be accessed through the World Wide Web at the following address:

http://www.energyanalysis.anl.gov/1-vol1.htm

Printed copies may be available through Argonne National Laborary in the US by contacting the following:

Mr D. Streets, PhD
Director, Policy and Economic Analysis Group
Decision and Information Sciences Division
Argonne National Laboratory
9700 South Cass Avenue, DIS/900
Argonne, IL 60439-4832
USA
Tel: + 1-708-252-3448
Fax: + 1-708-252-3206

Email: streetsd@smtplink.dis.anl.gov

EM Model
The EM Model is available free of charge from the World Bank on the World Wide Web at the following address:

http://www.worldbank.org/html/fpd/em/emhome.htm

Further information can be obtained by contacting:

Joseph Gilling.
World Bank, Industry and Energy Division,
Washington D.C.
USA
Tel: +1-202-473-3230
Fax: +1-202-477-0558

Tilman Herberg
GTZ, Energy and Transport Division
Eschborn
Germany
Tel: +49-6196-79-1619
Fax: +49-6196-79-7144

CEC Energy Technology Status Report

The last ETSR was published n 1991 but a new edition is expected to be available soon. There is a charge for this large document, but the price is very reasonable compared with other commercially available data.

The CEC's World Wide Web site can be accessed at: http://www.energy.ca/gov/

The ETSR can be ordered through the CEC's publications department at the following telephone number: +1-916-654-5200.

Technical information regarding the ETSR can be obtained by contacting:
Mr Pramod Kulkarni
Energy Technology Development Division
California Energy Commission
1516 Ninth Street
Sacremento, CA 95814
USA
Tel: +1-916-654-4637
Fax: +1-916-653-6010

E Source

Organisations must become members of E Source in order to access the various reports. Membership fees depend on the size and type of organisation but tend to be US$5000 and up per year.

E Source's World Wide Web site can be accessed at: http://www.esource.com/

Further information can also be obtained by contacting:
Tony Foster
E Source
1033 Walnut Street
Boulder, Colorado 80302-5114
USA
Tel: +1-303-440-8500
Fax: +1-303-440-8502
Email: esource@esource.com

ACEEE

A list of available publications and other information about ACEEE can be accessed thought their World Wide Web site at: http://solstice.crest.org/efficiency/aceee/index.htm

ACEEE publications are modestly priced (US$5 – 30) and can be ordered through:
American Council for an Energy-Efficiency Economy
2140 Shattuck Avenue, Suite 202
Berkeley, CA 94704
USA
Tel: +1-510-549-9914
Fax: +1-510-549-9914
Email: ace3-pubs%ace3-hq@ccmail.pnl.gov

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GREENTIE can be reached at the following:
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The Netherlands
Tel: +31-46-420-2203
Fax: +31-46-451-0839
Email: nlnovbas@ibmmail.com
Web: http://www.greentie.org

IKARUS, FIZ-Karlsruhe
This database is reportedly up to date. In addition there are plans to continue updating in 1998.

http://www.fiz-karlsruhe.de/peu/ika2.html

DECADES, IAEA
http://www.iaea.or.at/worldaton/inforesource/bulletin/bull372/bertel.html

CADDET Register
http://www.caddet-ee.org/register.htm

Appendix B

Gross Domestic Product and Gross Value Added

Instead of using the Gross Domestic Product (GDP) and growth thereof to determine the health of the South African economy, the Reserve Bank in accordance with the "Recommendations of the Revised System of Accounts 1993" utilises the term Gross Valued Added (GVA). Simply, GVA at basic prices reflects the amount receivable by the producer from the purchase for goods and services produced, less any tax payable, plus any subsidies receivable on such goods and services. The relationship between Gross Domestic Product and Gross Value Added (GVA) is described below.

Gross Domestic Product (GDP) at market prices
Less: tax on products
Add: subsidies on products
Gross Value Added (GVA) at basic prices

If the mitigation analysis is to make use of latest Reserve Bank national accounts, it should utilise data based on GVA at basic prices. GVA values (real and nominal) for 1988 to 1998 are in Table 5 in the text. This table also provides data on the GVA deflator and a GVA-derived inflation. The GVA deflator is defined as follows:

GVA deflator = Nominal GVA/Real GVA

To better understand nominal GVA, real GVA and the GVA deflator, consider an economy with only one good: bread. In any one year, nominal GVA is the total number of Rands spent on bread in that year (less taxes, plus subsidies). Real GVA is the number of loaves produced that year times the price of bread in some base year. The GVA deflator is the price of bread in that year relative to the price of bread in the base year. In an economy with many goods, nominal GVA, real GVA and the GVA deflator aggregates the many different prices and quantities. Nominal GVA measures the rand value of the output in the economy. Real GVA measure the amount of output – that is, output valued at constant (base-year) prices. The GDP deflator measures the price of the typical unit of output relative to its price in the base year.

We recommend that the GVA-derived inflation rate is used instead of a Consumer Price Index (CPI), or Producer Price Index (PPI). This is largely because the GVA deflator measures the prices (net of taxes and subsidies) of *all* goods and services produced as opposed to prices in a particular sector.[12] Note that in the Country Study Mitigation project GVA is only being used to provide a conversion factor for prices in years other than 1997 into 1997 Rands. It is not being used as a substitute for GDP in IDC's macroeconomic model.

12 This index applies a variable-weight rather than a fixed weight.

Appendix C

Results of Zimbabwe mitigation costing study – basis for marginal abatement cost curve

	Common Assumptions					Short run			
Reduction option	Z$/$CO_2$	Unit size	Unit type	Energy type (Saved)	Emission Reduction (tonCO_2/unit)	Units penetration 2010	Reduction in 2010 (million ton/yr)	Reduction in 2010 (%)	Energy saved 2010
1. Tillage	-1046.3	1	Tractor	Diesel	18.5	1 227	0.02	0.1	0.31
2. Efficient lighting	-543.0	1 000	Bulbs	El-coal	54.1	1 000	0.08	0.1	0.57
3. Geyser timeswitch	-171.9		Units	El-coal	1.3	61 000	0.15	0.5	0.82
4. Coalbed ammonia	-159.9	83	MW	Coal	808 131.3	1	0.96	2.9	8.51
5. Methane from sewerage	-135.9	1	Plant	El-coal	1203.8	10	0.97	3.0	0.13
6. Prepaymt meters	-107.3	200	Units	El-coal	1.9	3 000	0.98	3.0	0.06
7. Cokeoven gas	-104.5	15000000	1 diesel eqv	Diesel	43 941.9	1	1.02	3.1	0.59
8. Efficient motors	-99.3	1 000	kW	El coal	4.3	14 000	1.09	3.3	0.64
9. Efficient boilers	-23.0	100	tons	Coal	1051.4	635	1.75	5.4	0.00
10. Savings in industry	-14.0			In split			1.75	5.4	0.00
11. Efficient tobacco barns	0.1	1	barn	Coal	639.7	320	1.96	6.0	2.15
12. Pine Afforestatation	9.9	1	ha	Wood	29.4	60 000	3.43	10.3	10.37
13. Efficient furnaces	47.5	2	MW	Coal	7241.7	115	4.26	13.0	8.77
14. Biogas from landfills	24.4	1	Landfill	El-coal	447 828.5	1	4.71	14.4	4.71
15. Biogas from rural hsholds	48.0	1	Digesters	Wood	9.1	7500	4.78	14.6	0.62
16. Hydropower	65.1	0	kW	Coal	8.2	0	4.78	14.6	0.00
17. Solar geysers	238.2		Units	El-coal	2.9	61 000	4.95	15.1	1.84
18. Central PV electricity	564.4	1	kW	Coal	2.1	0	4.95	15.1	0.00
19. Power factor correction	6 687.0	1	MVAR	El-coal	778.5	234	5.13	15.7	1.92
20. Solar PV water pumps	27 566.3	3.5	kW		0.2	1 500	5.14	15.7	0.00
Totals	-1407.4				1 310 170.1				45.01
Total emission reduction:							32.70		
% Reduction of total emission								15.7%	

Table cont…

	Long run				Short run		Long run	
Reduction option	Units penetrating in 2030	Reduction in 2030 (mill ton/yr)	Reduction in 2030 (%)	Energy Saved (2030)	Total cost 2010 (millZ$)	Average cost 2010 (Z$/ton)	Total cost 2030 (millZ$)	Av.cost 2030 (Z$/ton)
1. Tillage	1 227	0.02	0.0	0.31	-22	-1046.3	-24	-1 046.3
2. Efficient lighting	5 000	0.29	0.5	2.85	-53	-691.9	-171	-582.0
3. Geyser timeswitch	91 000	0.41	0.7	1.22	-66	-430.0	-190	-465.6
4. Coalbed ammonia	1	1.22	2.1	8.51	-196	-203.3	-320	-262.6
5. Methane from sewerage	20	1.24	2.2	0.25	-197	-202.5	-324	-260.2
6. Prepaymt meters	3 000	1.25	2.2	0.06	-198	-201.9	-323	-259.5
7. Cokeoven gas	1	1.29	2.2	0.59	-203	-197.7	-328	-254.2
8. Efficient motors	61 200	1.56	2.7	2.80	-209	-192.2	-355	-227.8
9. Efficient boilers	2 000	3.66	6.4	22.14	-224	-127.8	-403	-110.1
10. Savings in industry		6.16	10.7	10.18	-224	-127.8	-438	-71.1
11. Efficient tobacco barns	660	6.58	11.5	4.44	-224	-114.4	-438	-66.5
12. Pine Afforestatation	100 000	9.53	16.6	26.75	-209	-61.0	-409	-42.9
13. Efficient furnaces	115	10.36	18.0	8.77	-170	-39.8	-369	-35.6
14. Biogas from landfills	1	10.81	18.8	4.71	-159	-33.7	-358	-33.1
15. Biogas from rural hsholds	10 500	10.90	19.0	1.00	-156	-32.6	-354	-32.4
16. Hydropower	450 000	14.60	25.4	38.92	-156	-32.6	-113	-7.7
17. Solar geysers	91 000	14.86	25.9	2.75	-114	-23.0	-51	-3.4
18. Central PV electricity	200 000	15.27	26.6	4.37	-114	-23.0	183	12.0
19. Power factor correction	854	15.94	27.8	7.00	1104	215.0	4629	290.4
20. Solar PV water pumps	1500	15.94	27.8	0.00	1112	216.6	4637	290.9
Totals				147.61				
Total emission reduction:		57.40						
% reduction of total CO_2 emission			27.8%					

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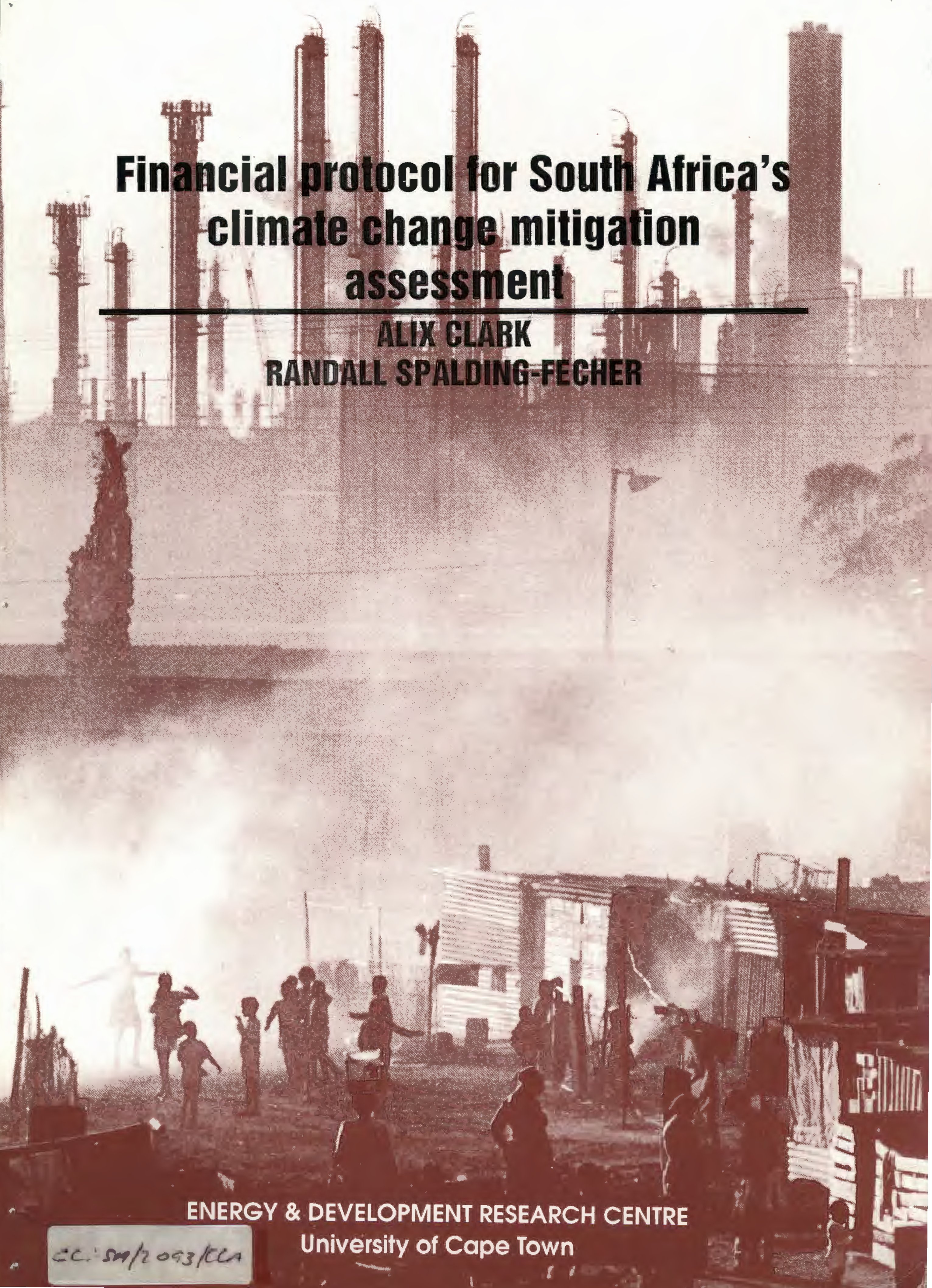

Financial protocol for South Africa's climate change mitigation assessment

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